Groove experience

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Groove Experience: Emotional and Physiological Responses to Groove-Based Music

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ABSTRACT

Theories of music and emotion suggest that subjective affective experience and physiological arousal are elicited by anticipation of musical-structural events. However, little is known about to what extent groove-based music elicits such expectancies, and consequently how it is experienced. Due to the repetitiveness of the groove, it was hypothesised that microtiming in groove might facilitate a type of arousal that is not peak-based, but rather reflects the groove state of listening, which has been conceptualized as a steady mental state in synchronization with the music. An initial qualitative interview study with three groove-based music producers and musicians investigated the subjective affective experience of groove, the extent to which musical structures facilitated the experience, and to what degree the experience could be understood as emotional. A second experimental study investigated the extent to which structural deviations within and across the groove affect physiological responses by measuring heart rate, skin conductance and respiration of 10 participants. The GEMS-model was used to investigate to what extent emotions and feelings were elicited. Interviews were also conducted to obtain subjective accounts of the experience. The results reveal that large-scale variations in groove-based music can be understood as 'peak events' that elicit 'peak physiological responses'. Effects of microtiming could not be identified using physiological measurements. A groove listening state was however reported in the interviews, albeit with differing understandings of its emotional quality. The research therefore poses implications for future investigations of alternative conceptualizations of the affective experience of groove-based music.

I. INTRODUCTION

There are properties of music that have the ability to tap into our emotions, change our moods and send shivers down our spines. It has become increasingly common to view such responses as reflective of the multicomponential nature of emotion. Scherer (2004; 2005) distinguishes between cognitive, motor-expressive, physiological responses and subjective feelings elicited by music and sees an emotion episode as including most or all of these psychological effects. He stresses the often overlooked difference between emotions and feelings, stating that feelings should be understood as the experiential result of an emotion episode, while emotions are more closely related to functional effects and humans' survival mechanisms. In his view, researchers investigating affective responses to music should take feelings as points of departure and study the ways in which changes in the components in an emotion episode are *felt*.

Unfortunately, researchers investigating the structural properties of music that elicit emotional arousal have largely ignored popular music, and groove-based music in particular. It seems to have been assumed that the complex and teleologically composed structures of classical music are more adept for stimulating listeners affectively, while immediate and repetitive popular music is preferred for socio-cultural studies. Physiological responses to music has been empirically researched through qualitative reports (Sloboda 1991), hand-raising (Panksepp 1995), button-pressing (Waterman 1996) and physiological measurements (Krumhansl 1997; Rickard 2004; Guhn et al. 2007; Grewe et al. 2007; Gomez & Danuser 2007). By studying responses in for instance heart rate, skin conductance and respiration, researchers have been able to trace the intrinsic sources for arousal in music. The theory most often supported in these studies is Meyer's theory of expectation (1956). Here Meyer draws on Gestalt theory when proposing that structural events in music are perceptual tendencies. Focusing on teleologically composed classical music, he claims that through inhibition of, deviation from and delay of tendencies, expectations are frustrated and the listener experiences tension and arousal. In one of the first empirical studies of this theory, such structures were named "peak events" (e.g. sudden harmonic change, appoggiaturas, descending cycle of fifths, see Sloboda 1991), and they have been directly identified as eliciting 'peak physiological responses' or 'chills' in listeners (Guhn et al. 2007). A few physiological studies include popular music in their experimental designs, however the structural characteristics of the music are largely ignored. Panksepp's study (1995) used exclusively songs of the popular genre, but the discussion focused on the general emotional expression of the music, rather than specific musical structures. Grewe et al. (2007) used a number of popular genres, including groove-based music, but as the classical pieces seemed to foster more consistent responses, only these were chosen for closer analysis and discussion. There are, in short, no empirical investigations of physiological arousal elicited by groove-based music and the structures that may facilitate such responses.

Huron's theory of anticipation and the prediction-effect (2006) is a more recent contribution to the theoretical approaches to emotional arousal. In addition to effects of deviations, he states that successful prediction of structural events elicits positive cognitive responses. The prediction-effect relies on repetition and familiarity. The more a pattern is repeated the stronger our expectations towards similar patterns become and the more likely we are to successfully predict them. Popular music, and groove-based music in particular, might therefore seem a particularly suitable route to emotional stimulation through prediction, due to its repetitive structure. However, this hypothesis has not been empirically investigated.

Zbikowski (2004) provides a useful structural definition of groove as: "a large scale, multilayered pattern that involves both pitch and rhythmic materials, and whose repetitions form the basis for either a portion or all of a particular tune" (p. 275). Such structures can be found in a number of music genres, such as funk, soul, hiphop, triphop, drum'n bass,

house, jazz and world music. In recent years, groove has received some psychological-theoretical attention. Madison (2006) found that the desire to move and dance was the second largest factor in factor analysis of subjective ratings of groove-based music. A recurring feature in cognitive approaches is the incorporation of embodied knowledge. This concept refers to cognition "as activity that is structured by the body situated in its environment – that is, as embodied action" (Iyer 2002: 389). Zbikowski (2004) argues that groove invites bodily motion because of the structural similarities it shares with rhythmic regularities in the human body, such as heartbeat, breathing and walking. Iyer (2002) directs an ecological approach to the perception of microtiming in groove. Microtiming is a rhythmic structure in which phenomenal accents are microscopically shifted ahead or behind their metrical locations, playing rhythmic events "late" or "early". Iyer sees these structures as invariants that facilitate perception of the source behind the rhythmic event, i.e. the movement and initiation behind the sound and the body/entity that produces it. As well as incorporating embodied knowledge, Pressing (2002) considers the cognitive component of the emotional experience of groove, which he attributes to what Huron would name the prediction effect: "[Groove] arises from refinements of special conditions of heightened cognitive prediction of time" (Pressing 2002: 196). Furthermore, he claims that arousal is elicited by perceptual rivalry, multiplicity, tension and ambiguity in groove-based music, as these structures facilitate cognitive dissonance and uncertainty.

Coming in from a humanistic perspective, Danielsen's (2006) phenomenological account of the experiences of funk music provides some compelling hypotheses of the experience of groove. She describes the groove mode of listening as phenomenologically different from the experience of listening to more teleologically composed music (i.e. classical). Rather than directing expectations forward, based on tendencies perceived in the past, listeners in a groove mode of listening are immersed into an "eternal present". Because the music is repetitive, attention is directed inwards, to what is happening at that moment. However, this does not mean that time, and groove, is static. Danielsen sees this way of listening as a mental "moving together with the music" because the listener's attention is always synchronized with the forward-moving and repetitive groove. Although the music is repeated, the time in which it is experienced is not. In this sense, repetition is not habituating, but enhancing.

In terms of structure, groove-based music and groove is often analyzed on two levels; within and across the repeated basic unit of the groove (usually between 1-2 measures). In Danielsen's study (2006) the primary focus is on structural tension occurring within the basic unit, such as rhythmic displacement, counter- and cross-rhythmic patterns and microtiming. Microtiming is traditionally seen as a performance strategy for adding expressivity and tension to rhythmic patterns, and in studies of groove, it is recognized as an integrated part of the groove performance- and production-style (Waadeland 2001; Danielsen 2006, Danielsen, forthcoming).

Although microtiming adds tension within the repetitive groove, larger-scale variations often occur across the basic unit. Danielsen (2006) describes the function of instrumental breaks in funk. These are points where the groove is momentarily replaced with one or a few instruments performing a short and intensified rhythmic gesture, temporarily disrupting the repetition and taking the listener out of the groove state of listening. In Butler's analyses of electronic dance music (2006), he describes how large-scale changes create structural tension and ambiguity. By gradually introducing textural layers, tension is progressively built in the groove, letting each new layer add something to the rhythmic design while completing the texture of the groove over time. Temporary removal of textural layers is another effective variation. Removing the drumbeat is a powerful way for a DJ to stimulate his clubbers. It achieves an anacrustic effect, building tension towards the return of the layer that has been removed.

In a sense, large-scale variations in groove-based music can be interpreted as structural deviations similar in theory to those described by Meyer (1956): Gradually introducing or temporarily removing textural layers inhibits the completion of the groove as a full-textured entity, while instrumental breaks abruptly deviate from the repetitive groove. However, as groove-based music is not teleologically composed, to what extent will these variations function as 'peak events' and elicit 'peak physiological responses'? Furthermore, microtiming can be seen as deviations from quantized metrical locations occurring within the basic unit. Although microtiming is an integrated part of the performance- and production-style of groove, on the level of perception one might expect that they facilitate a certain degree of tension and arousal. However, even if we understand microtiming as deviations, they manifest themselves on a different level than large-scale variations. Since they are microscopic and constantly repeated – because the basic unit is constantly repeated – they are not as obviously deviant as large-scale variations. If we assume that microtiming stimulates expectations, although more subtly than large-scale variations, one might expect that they will be reflected in physiological responses. The groove mode of listening proposed by Danielsen (2006) seems less compatible with peak-based arousal and we might imagine that "moving together with the groove" elicits a more steady and sustained level of arousal. To what extent will structural deviations within the repeated basic unit of the groove be reflected in physiological arousal? In addition to these questions concerning physiology in particular, the cognitive and phenomenological theories of the experience of groove lack empirical support. These theories give reason to suspect that there are sources for affective experience in the structures of groove-based music. But to what extent do listeners experience groove emotionally and what characterizes this experience?

II. FIRST STUDY: A QUALITATIVE EXPLORATION

The first qualitative study investigated the subjective affective experience of groove. Groove-based musicians/producers were interviewed, as it was hoped that their skills and knowledge of the composition and performance of groove-based music, as well as their general experience as groove-based music listeners, might yield rich accounts of the extent to which the musical structure is influential to the experiences induced. The research questions

for this study were: What characterizes the affective experience of groove and to what extent do the structural characteristics of groove-based music affect this experience? Furthermore, the study investigated the extent to which the experience could be understood as emotional.

A. Method

1) Participants. Three participants were recruited through personal contacts of the author. They were all male individuals currently active in groove-based music milieus in London, performing and producing within a number of different groove-based genres (e.g. hiphop, jazz-fusion, world music, R'nB, drum'n bass). Their age ranged from 28 to 49. In the following, they will be referred to with their first initial.

2) Procedure and Analysis. Semi-structured interviews were conducted and recorded at the homes or studios of the participants, and the duration was approximately 1½ hrs. Participants were asked to choose a piece of groove-based music that they particularly responded to. It was hoped that listening to actual music during the interviews would facilitate discussion and provide concrete musical examples that would help them articulate and pinpoint structures and sources for their responses. The interviews were analyzed using Interpretative Phenomenological Analysis (see Smith 2001).

B. Results and Discussion

3) Getting into the Groove. One expression frequently reoccurred among all three participants when describing their experiences of groove-based music: getting into the groove. This phrase seemed to reflect a mental state: the participants spoke of "tuning into" the interlocking of rhythms and experienced becoming "in sync" with the music. Repetition was named the uttermost important ingredient in the structure of groove and the facilitation of this state of listening:

> It's just going backwards and forwards and backwards and forwards and backwards and forwards and you settle into a groove because it's repetitious and eventually you'll know where it is, and you can kind of move into it (A).

In the sense described here, repetitive groove-based music is not experienced as static, but rather as moving in a circular manner. Reflections of this quality seem to stand in accordance with Danielsen's phenomenological theory of groove, in which the repetitiveness causes the listener to mentally "move with the music" (Danielsen 2006).

The effects of repetition were further described as facilitating constant feelings of anticipation:

> Whatever groove you have, there's always gonna be an element in it that's just always on time and you know when its gonna be there. It's always solidly, solidly bang on time! (…). A repetitive drumbeat is the most important in having a great groove. And you know where… you can *feel* where the drums are gonna hit (L).

These reflections fit well with the feelings of pleasantness elicited by what Huron refers to as "the prediction effect" (Huron 2006). The rhythmic regularity of the groove facilitates accurate temporal predictions, which elicit positively valenced cognitive responses. It seems Pressing's (2002) theoretical suggestions for such a cognitive route to arousal have some resonance in the subjective reflections in the present study.

4) Effects of Microtiming and Change. Both L and A emphasized the significance of microtiming and its enhancement of the groove state of listening. L seemed to experience microtiming as having an anacrustic function, contributing to the feelings of anticipation:

> If you had a beat where you had a hit on the first and the third beat of every bar [in a 4/4 meter], and it's always there within the beat, and you knew it was there and you could feel it being there, and the other [microtemporally shifted] beats are there to sort of accent the whole rhythm in general, that kind of make you stumble onto those beats that you know are gonna be there, almost like you roll onto them (L).

The stumble-analogy is particularly illustrative: walking involves a pattern of impacts with the ground in a rhythmic and regular pattern. Because of the repetition and cyclicity of this motor-expressive rhythm, each impact is highly predicted. When stumbling on something, another impact occurs unexpectedly, resulting in an acceleration of speed and movement towards the predicted impact. In a way, the stumble is a deviation from a structural tendency, in the sense described by Meyer (1956), as the unexpected event inhibits the regularity of the rhythm in the walk. Furthermore, the words used by L to describe this experience seem to fit well with Iyer's (2002) and Zbikowski's (2004) theories of embodied knowledge, as motor-expressive behavior is related to rhythm perception. However, the subjective reflections in this study cannot be confidently inferred to reflect cognitive processes in a one-to-one relationship.

Interestingly, one of the participants, who was a drummer, seemed aware of the experiential effect of microtiming in groove but had a hard time identifying its source, referring to it simply as: "one of those little *je ne sais quois*" (T). One might expect that as a performer he would know how such structures were facilitated. However, his struggle to identify the exact strategies behind this experience precisely denotes microrhythmic structures as subtle and microscopic. They are not obvious deviations, but an integrated part of the stylistic expression in groove. It is worth keeping T's reflections in mind when interpreting the highly detailed descriptions of L and A, who were both producers. Without the practical knowledge achieved from digitally programming grooves, microrhythmic structures might not be consciously experienced.

Large-scale changes occurring across the basic unit, such as drum-beaks, hooks and gradual introduction and temporary removal of textural layers, were reported by all participants as influencing their experiences, eliciting feelings of anticipation and expectation. It might therefore seem that the experience of groove is somewhat similar to that of more teleologically composed music, in which arousal is elicited by inhibition of structural tendencies. However, a reflection made by A suggests that in the case of groove, these structures may in fact have a somewhat different function:

> The way it all sits together, it's got you hooked in a really rhythmic way. And then you just sit and wait. And the groove sits on that for ages, and you just wait and wait, and you can dance to that rhythm all night really (…), you're just waiting for it, waiting

> in anticipation and whether it changes or not, who gives a damn! (…) What it does whilst you're waiting for it, that's the trump of a tune for me (A).

Although he anticipates the changes, it is not the changes themselves which are the experiential goal. The groove is not supposed to lead up to these changes, but the changes are meant to strengthen the experience during the groove.

5) *Feelings and Emotional responses.* Although participants reported experiencing pleasantness from prediction and feelings of anticipation from microtiming and large-scale changes when listening to groove-based music, it leaves the question whether these are emotional experiences. In fact, all three participants used the word "emotional" in their interviews, but their definitions of emotionality seemed to differ. L was the most confident in his recognition of the experience as emotional and reported experiencing feelings of joy. A explicitly rejected groove's ability to elicit specific emotions, but described the experience more in terms of feelings associated with the physical effect of groove. Interestingly, he reflected upon how a physical reaction could be interpreted as emotional:

> I would probably be nodding my head and getting really into it. And when I'm physically getting into it I would say that feels good. But the feeling would transfer from a physical feeling to an emotional response. So I suppose it would start being physical, but then that would make me feel good, so that's an emotional thing, isn't it (A).

To A, the pleasantness associated with moving to the music was seen as a more general emotional reaction, rather than eliciting specific emotions. When participants were asked about their physiological responses to groove, their answers revealed considerable heterogeneity. L seemed to recall experiencing 'chills' elicited by groove-based music:

> It's like a sort of tingling feeling I get in my back and my chest… It's like fizzing, kind of like sherbert or something, inside me (L).

Contrastingly, A explicitly rejected groove's ability to elicit 'chills', while T seemed uncertain about his physiological reactions to groove-based music. It seems the participants had differing understandings of the ways in which emotional experiences were elicited by groove-based music. This multiplicity is perhaps a reflection of the different components of an emotional response (2004; 2005). Feelings of joy, pleasantness and anticipation are cognitive effects; feeling like wanting to dance is a physical and motor-expressive response; a 'fizzing' feeling is indicative of physiological arousal. As feelings are defined by the changes felt in all or most of the different components, one might interpret the different accounts in the interviews as descriptions of affective feelings elicited by groove-based music.

C. Summary and Implications for Second Study

The findings from this study reveal that there seems to be a certain way of listening to groove-based music, referred to as getting into the groove, which stands in accordance with Danielsen's theory of "moving together with the music" (2006). Groove also seems to elicit feelings of anticipation and pleasantness, which Huron attributes the prediction effect (Huron 2006). Furthermore, microtiming emerged as a structure in groove-based music that particularly influenced this experience, albeit only consciously in terms of production. Variations across the basic units? were also recognized as affecting the experience. However, the feelings of anticipation elicited by these changes do not necessarily denote these events as teleological goals in experience. Finally, the differing recognition of the emotional quality of the experience of groove reflects the multicomponential nature of emotional experience.

The findings selected for investigation in the second study resulted from the tendencies and contradictions that emerged from the interviews. There were indications that structures in groove-based music stimulate listeners through feelings of anticipation, both due to microtiming and large-scale variations. However, physiological arousal was not reported by all participants and the sources for and quality of physiological responses were not revealed in detail. Therefore it was decided to investigate physiological responses to groove-based music in an experimental context.

III. SECOND STUDY: A PHYSIOLOGICAL INVESTIGATION

This study investigated the physiological and emotional responses to groove-based music in a laboratory setting. Previous research has shown that stimulation of expectation through structural deviations in classical music elicits physiological arousal (e.g. Sloboda 1991, Guhn et al. 2007). In the present study, these tendencies were investigated in groove-based music by use of physiological measurements. The research questions were: What characterizes physiological responses to groove-based music and to what extent are its structural characteristics, such as large-scale variations and microtiming, reflected in these responses? Furthermore, feelings, emotions and affective states elicited by groove-based music were explored with scale-ratings.

D. Method

5) Participants. 10 participants (3 females and 7 males) were recruited from the University of Sheffield music department and through personal contacts of the author. The mean age was 23.7 years (SD=5.4). From ratings on a 5-point likert scale, it was revealed that they on average considered groove to be one of their favourite genres of music (mean=4.3, St.d=0.82).

6) Apparatus. Physiological responses were measured using biofeedback hardware and software Procomp Infiniti and BioGraph Infiniti (2.5.3) via a Dell LATITUDE D505 laptop. Measurements were taken for heart rate (HR) in beats per minute, skin conductance (SC) in microsiemens and respiration (RESP) in breaths per minute. A macbook OS X 10.4.11 Intel played the music to the participants via closed headphones at a loud but comfortable sound level.

The GEMS list of emotions-, feelings- and affect labels (Zentner et al. 2008) was used to design a 5-point likert scale to record participants' emotional and affective experiences of the music. These labels have been shown to particularly suit investigations of musical emotions. The list contains nine categories of labels from which, in this study, two labels were used: 'wonder' (happy, moved), 'transcendence' (inspired,

thrills), 'tenderness' (sensual, tender), 'nostalgia' (dreamy, melancholic), 'peacefulness' (relaxed, meditative), 'power' (energetic, fiery), 'joyful activation' (stimulated, joyful, makes me want to dance), 'tension' (agitated, tense) and 'sadness' (sad, sorrowful). Three labels were used from the category 'joyful activation', as this category showed prominence in measurements of the experience of groove-based genres in previous research (Zentner et al. 2008).

7) Stimuli. The stimuli consisted of one piece chosen by the participant and two pieces chosen by the researcher which were played to the participants in their entirety. In accordance with previous research, the expectation was that music with which participants had a personal connection would foster rich results (Panksepp 1995; Rickard 2004). Participants were asked to choose a piece they felt they particularly responded to. The pieces chosen were of a wide range of groove-based genres, such as hiphop, drum'n bass, soul, jazz, funk and world music. The experimenter-chosen pieces were chosen for their assumed familiarity among the participants, since previous research reveals stronger emotional reactions to familiar music (e.g. Rickard 2004). The pieces were also chosen due to their differing expressions and structural characteristics. "Sex Machine" (1970) by James Brown is a classic funk tune with an up-tempo expression commonly associated with dancing. Its structures include microtiming, syncopation, displacement and repetition, as well as larger-scale variations, such as piano solos, horn breaks and a bridge. The lyrics comprise mostly of James Brown communicating with his band and encouraging his listeners to dance. "Teardrop" (1998) is a piece by the triphop band Massive Attack. Triphop is a genre combining down-tempo hiphop beats with the sounds of ambient electronica. Its expression, often amplified by poetic lyrics, is believed to encourage contemplative listening rather than dancing. The musical structures of "Teardrop" include gradual introduction of textural layers, temporary removal of textural layers while maintaining groove-based through repetition.

8) Procedure. Experiments were held at the University of Sheffield music department. Each session lasted approximately one hour. Participants were seated facing a wall with their arms on a table in front of them. After being attached to electrodes, participants were asked to relax, focus on the music and not move while measurements were being taken to avoid measurement noise. The experiment had a repeated-measures design, in which the pieces were balanced in order. Each piece was preceded by two minutes of silence in order to obtain a "resting state" baseline measure with which music responses could be compared. After each piece, participants filled out the GEMS questionnaire and rated their familiarity with and liking of the experimenter-chosen pieces on 5-point likert scales. 15 minute long semi-structured interviews were conducted and recorded immediately after the experiment, in which participants were asked to describe their experiences and report any sections or parts of the music they had particularly responded to.

9) Analysis. The physiological data were analyzed using BioGraph Infiniti. All responses were visually screened for measurement noise and artifacts, which were rejected from calculations. Due to the discovered patterns of recovery from the attachment of sensors in the baseline-measure of SC, it was decided to use only the last 10 sc of this measure as baseline as this would more closely represent a "resting state". The baseline-periods for HR and RESP exhibited no such patterns and were therefore used in their entirety.

As well as calculating the average physiological arousal for the whole pieces, the first three minutes of each piece were divided into one-minute segments. It was suspected that averaging over the whole piece might not fully capture the nature of the responses, as music might be arousing at different times. Only values for the first three minutes were used in this analysis, as some participant-chosen pieces did not exceed this time length. All absolute values were normalized over their respective base-line periods to obtain measures of relative percent change from baseline controlled for individual differences.

E. Results and Discussion

11) Effects of familiarity and liking. To investigate any relationship between familiarity, liking and overall arousal for experimenter-chosen pieces, Pearson's correlations tests were conducted. A significant positive correlation of familiarity with liking was revealed for "Sex Machine" ($r=0.867$, $df=8$, $p=0.001$), but not for "Teardrop" ($r=0.436$, $df=7$, $p=0.241$), giving some indications of accordance with previous research showing that pieces with which listeners are familiar also seem to be liked (e.g. Rickard & Ritossa 2004). No significant correlations were found for familiarity or liking with overall arousal. These results most probably reflect the small number of participants and uniformly high ratings of familiarity and liking for both pieces ("Sex Machine" familiarity mean=4.6, St.d.=0.70, liking mean=4.4, St.d.=0.84, "Teardrop" familiarity mean=4.22, St.d=0.83, liking mean=4.44, St.d.=0.73).

10) Effects of music. Dependent t-tests compared levels of physiological arousal during each of the one-minute segments with baseline-periods. The results are provided in table 1. Levels of arousal were significantly higher in SC during participant-chosen pieces for all three minutes, but only the 1st minute segment was significantly higher in HR. None of the minutes measured in RESP were significantly higher than baseline. During "Teardrop", the 1st minute segment was significantly higher in SC and RESP. The 1st minute segment was significantly higher than baseline in SC only for "Sex Machine". These results indicate that groove-based music physiologically arouses listeners, but only for a certain amount of time and not in all physiological parameters. Figure 1 presents levels of arousal in SC for all one-minute segments in each piece. The graph indicates a tendency of habituation in arousal for the experimenter-chosen pieces. However, as levels of arousal in the last two minutes were not statistically significant, the apparent decrease from the first minute should be interpreted with caution. Nonetheless, the statistically significant levels of arousal in all three minutes for the participant-chosen pieces and the lack of decrease indicates that groove-based music with which listeners have a personal relationship is less susceptible to habituation. It should, however, be noted that only the first three minutes of the

pieces were analyzed, and it is possible that the arousal during the rest of the pieces exhibited other patterns.

Table 1. Mean relative percent increase from baseline in HR, SC and RESP during one-minute epochs. *p<0.05, 2-tailed t.

Teardrop (df=8)					
		Mean	*St.d.*	*t*	*p*
HR	1st min	3.0	5.2	1.73	0.122
	2nd min	2.6	6.2	1.22	0.256
	3rd min	3.3	7.3	1.37	0.208
SC	1st min	24.8	20.1	3.70	0.006*
	2nd min	23.2	31.0	2.24	0.055
	3rd min	11.2	27.8	1.21	0.260
RESP	1st min	20.6	22.6	2.72	0.026*
	2nd min	13.9	21.0	1.98	0.083
	3rd min	14.0	35.6	1.15	0.283
Sex Machine (df=9)					
		Mean	*St.d.*	*t*	*P*
HR	1st min	3.1	5.0	1.97	0.080
	2nd min	2.1	6.0	1.11	0.295
	3rd min	2.2	6.3	1.10	0.300
SC	1st min	16.7	16.4	3.21	0.011*
	2nd min	10.9	16.8	2.05	0.071
	3rd min	5.0	20.1	0.78	0.453
RESP	1st min	10.7	24.6	1.37	0.203
	2nd min	12.3	41.4	0.94	0.372
	3rd min	8.9	21.2	1.32	0.218
Participant-chosen pieces (df=9)					
		Mean	*St.d.*	*t*	*p*
HR	1st min	29.0	3.0	3.02	0.014*
	2nd min	3.9	5.5	2.24	0.052
	3rd min	3.4	8.2	1.3	0.225
SC	1st min	24.3	20.6	3.73	0.005*
	2nd min	34.2	31.6	3.42	0.008*
	3rd min	26.4	23.5	3.56	0.006*
RESP	1st min	12.4	22.8	1.72	0.119
	2nd min	14.4	31.9	1.43	0.187
	3rd min	13.8	33.3	1.31	1.223

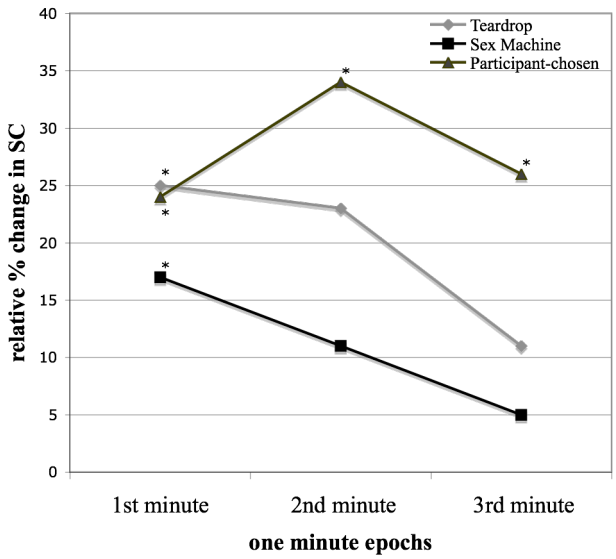

Figure 1. Mean relative percent change from baseline in SC during one-minute segments. * Statistically significant (p<0.05) increase from baseline, defined as 0%.

These indications were further supported by results from repeated measures one-way ANOVA's, which were conducted to investigate differences in arousal between the three music conditions. A significant main effect of music condition was found in SC ($F(2,16)=7.153$, $p=0.006$), but not in HR ($F(2,16)=0.89$, $p=0.915$) or RESP ($F(2,16)=0.126$, $p=0.883$). A Bonferroni post-hoc test revealed that participant-chosen pieces elicited significantly higher arousal in SC (mean=29%, St.d=22%) compared to "Teardrop" (mean=3%. St.d=17%) ($p=0.025$), but not compared to "Sex Machine" (mean=6 %, St.d=14%) ($p=0.104$). No statistically significant differences were found between the two experimenter chosen pieces ($p=1$). Therefore, it seems that groove-based music with which listeners have a personal connection elicits higher levels of arousal than pieces with which listeners simply like and are familiar with.

12) 'Peak responses' to 'peak events'. When visually screening physiological responses for recurring patterns, several peaks were identified and matched with corresponding musical structures that could be interpreted as 'peak events'. These structures include introduction of new textural layers, temporary removal of textural layers, high pitch vocal events, instrumental breaks, harmonic variations in otherwise repetitive harmonic progressions, introduction of new formal sections (e.g. B sections, bridges, choruses), metrical dissonance and displacement. In the experimenter-chosen pieces, responses to such events showed consistency across several participants. However, an interesting observation was that 'peak responses' did not always occur across physiological parameters for each participant. The highest consistency was observed in the participant-chosen pieces. RESP responses exhibited high levels of variability and should therefore be interpreted with caution, as this physiological parameter is subject to conscious alteration (i.e. the participant could consciously choose to breathe faster or slower).

In the interviews, temporary removal of textural layers was reported as the most stimulating structure. Participant 1's responses provide a good example of how such structures might be reflected in HR, SC and RESP. Her chosen piece was "Jimmi Diggin' Cats" (1993) by the hiphop group Digable Planets. At several instances during the otherwise repetitive groove, the whole groove or most of the layers in it are removed for the last half of a measure, leaving the rapper to conclude the basic unit of the groove on his own. At other times, the groove is replaced with interludes of mellow talking accompanied by a quiet synthesizer pattern. At each of the moments when the groove or the removed layers are reintroduced, the participant's responses exhibit peaks, as can be seen in figure 2. It seems that at these moments, the participant experienced anticipation of the return of the groove, and once it was reintroduced, arousal increased. This participant's qualitative reflections during the identifications of these events in the interview further supports this assumption:

> I feel like I can still hear the groove (…), and when the beat finally comes back in it just reaffirms what I've been listening to and I think it's then even more intensified, because I know it already and it makes sense, and I can just get with it (…). It just reinforces what I really like about it. Like, it's been extracted away from me, so I'm a bit lusting for it (P1).

Keeping the beat in mind while it is removed creates anticipation and satisfaction at the eventual return of the beat. For this participant, these cognitive processes and feelings of anticipation seem to be reflected in her physiological responses.

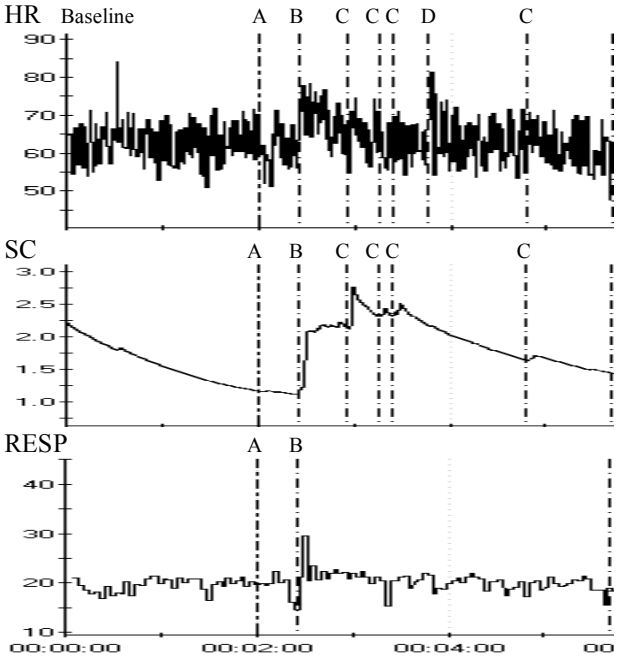

Figure 2. Peaks in HR, SC and RESP of participant 1 from temporary removal of textural layers in "Jimmi Diggin Cats". HR y-axis=beats per minute, SC y-axis=microsiemens, RESP y-axis=breaths per minute. All x-axes=time in minutes of recording session. A=introduction of music. B=first introduction of drumbeat. C=return of drumbeat/groove after temporary removal. D=drum break.

Several musical structures in "Sex Machine" elicited 'peak responses'. These include introduction of new textural layers (piano solos), introduction of formal sections (the bridge) and high pitch vocal events (James Brown's screams and vocal hooks). However, the structural events that elicited the most consistent responses and that were mentioned most frequently during the interviews were the horn breaks. A characteristic of James Brown is to vocally announce his breaks, explicitly facilitating anticipation of their arrival. In "Sex Machine" there are three such horn breaks, all of which are announced approx. 15 seconds in advance; at the beginning of the piece, at the return of the groove after the bridge and at the end of the piece. Peaks were most frequent at the return of the groove after the bridge. However, they were not observed in all physiological parameters for all participants. Figure 3 shows examples of physiological manifestations of three participants at the time of this horn break. Participant 3's reflections during the interview provide a useful subjective account of the experience of these instrumental breaks:

> I remember feeling, sort of anticipating, like, what's it gonna be this time, what's it gonna be next time… (P3).

Due perhaps to the expectations elicited vocally by James Brown, the participant anticipated these changes. Furthermore, as this music was highly familiar to all participants, the anticipation might in part stem from actually knowing that the break is approaching.

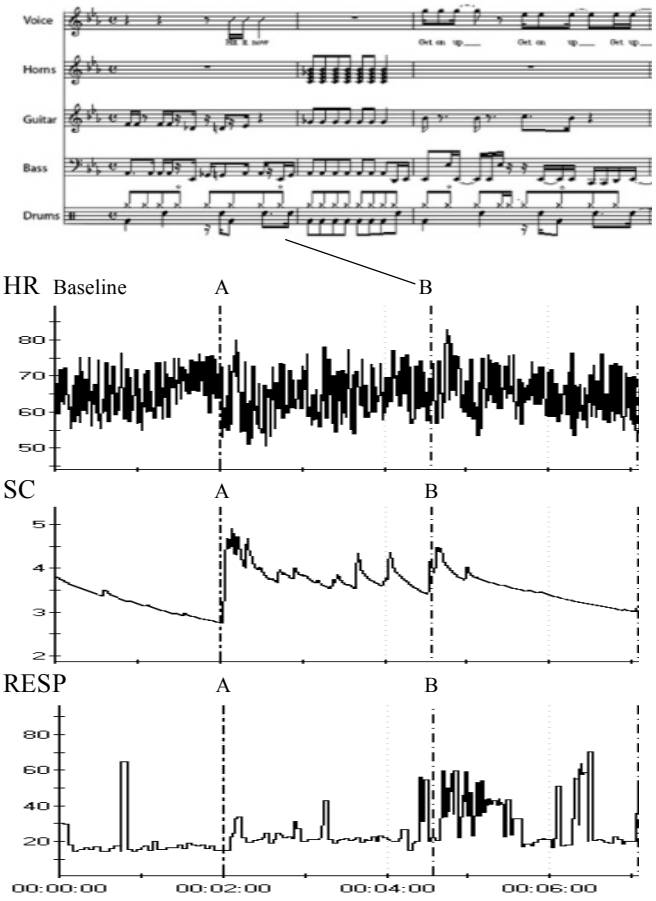

Figure 3. Peaks at horn break in "Sex Machine". HR of participant 1, y-axis=beats per minute. SC of participant 5, y-axis=microsiemens. RESP of participant 2, y-axis=breaths per minute. All x-axes=time in minutes of recording session. A=music begins. B=horn break. Length of music score does not correspond proportionally in time with physiological graphs.

"Teardrop" elicited 'peak responses' at structural events such as temporary removal of textural layers, harmonic variations in otherwise repetitive harmonic progression and high pitch vocal events. The structures that elicited the most physiological peaks occurred during the introduction. The first minute of the piece provides a good example of how gradual introduction of textural layers might be experienced physiologically. Participants' physiological responses exhibited peaks at three moments in this introduction, particularly at the introduction of the harpsichord, the introduction of the bass and piano and the final entry of the voice. Figure 4 presents physiological responses of three different participants at these moments. The introduction was identified as particularly arousing by several participants during the interviews, especially the moment when the piano and bass is introduced. Participant 5 described the experience with words similar to those used by the participants in the first study when describing the groove state of listening:

> It's the beat, I think that's what it is, it's the dark bass, when that kicks in, I'm just away then, I'm hooked (P5).

The gradual introduction can be understood as building tension towards the entry of the groove in its full form, causing the feelings of anticipation to enhance the groove mode of listening. Instead of effortlessly getting into the groove at the first instance, the gradual introduction of the groove's layers and the feelings of anticipation amplify the pleasantness of the groove state of listening when it is finally entered. These processes might explain the observed peaks at the gradual introduction of textural layers that emerged as a tendency among the participants in this study.

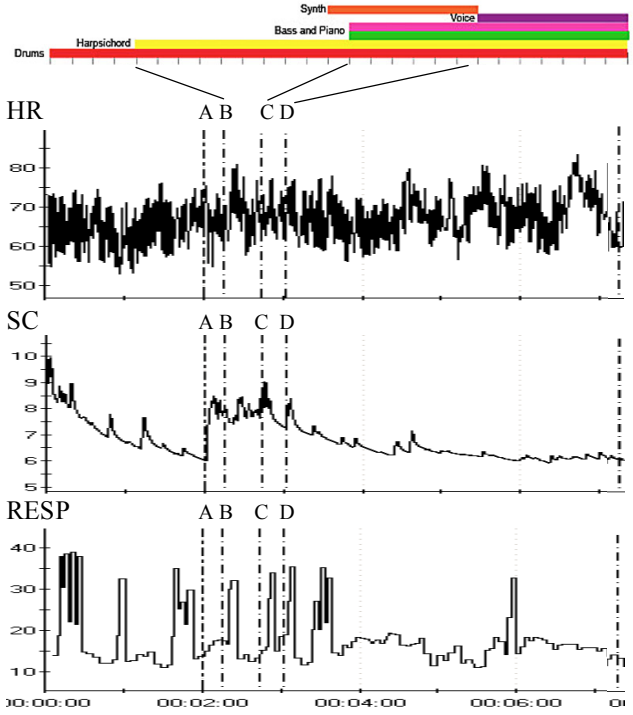

Figure 4. Peaks at gradual introduction of new textural layers in the intro of "Teardrop". H of participant 1, y-axis=beats per minute. SC of participant 7, y-axis=microsiemens. RESP of participant 6, y-axis=breaths per minute. All x-axes=time in minutes of recording session. A=music begins. B=intro of harpsichord. C=intro of bass and piano. D=intro of vocals. Length of textural graph does not correspond proportionally in time with physiological graphs.

Microtiming was not mentioned by any of the participants in the interviews, supporting the indication from the first study that these structures are primarily experienced consciously by producers. It should be noted that the responses of two participants exhibited arousal resembling a heightened response sustained throughout the music. However, the large majority of physiological responses of the participants in this study exhibited peaks that seemed to be elicited by large-scale events occurring across the basic unit of the groove.

13) GEMS-scale ratings. Repeated measures one-way ANOVA's were applied to investigate any differences in emotions, affects and feelings elicited by the three music conditions, as rated on the GEMS questionnaire. Significant differences were found for 7 of the 9 GEMS categories, as can be seen in table 2. The significant differences between music conditions that were revealed by Bonferroni post-hoc tests are presented in figure 5. These results indicate that groove-based music elicits differing emotions, feelings and affective states depending on the expression and genre of the music.

Table 2. Significant main effects, mean ratings and standard deviations of GEMS ratings. *p<0.05, df=2,16

			Teardrop		Sex Machine		Participant-chosen	
	F	*p*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Won.	0.29	0.755	3.67	0.50	3.67	0.87	3.83	0.66
Tran.	2.26	0.136	3.28	0.71	3.50	1.00	4.00	0.66
Tend.	8.54	0.003*	3.22	1.00	1.94	0.53	2.39	1.11
Nost.	14.88	0.001*	3.28	1.15	1.28	0.44	1.83	0.83
Peac.	61.19	0.001*	4.28	0.44	1.89	0.55	2.00	0.71
Pow.	26.06	0.001*	1.44	0.39	3.78	1.09	4.11	0.99
J.Act.	12.87	0.001*	2.59	0.76	4.11	0.67	3.89	0.67
Tens.	1.96	0.173	1.50	0.75	1.61	0.99	2.28	1.64
Sadn.	4.17	0.035*	1.94	0.77	1.00	0.00	1.39	0.56

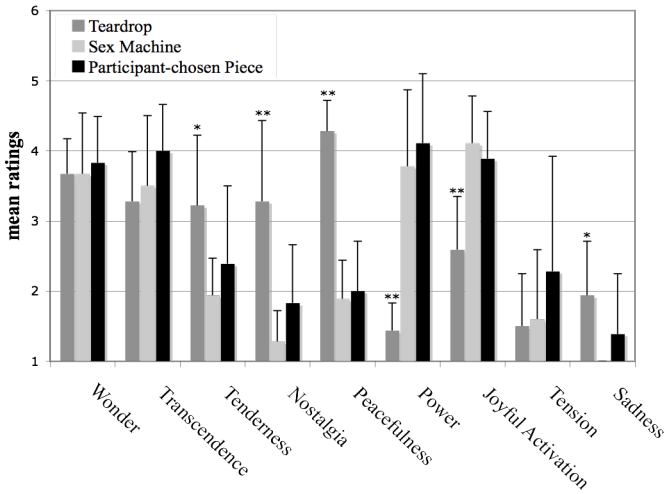

Figure 5. Mean GEMS-ratings. * significantly different from "Sex Machine". ** significantly different from "Sex Machine" and participant-chosen pieces. p<0.05. Error bars=St.d.

It seems that music with an up-beat expression, such as the funk tune "Sex Machine", particularly facilitates feelings of positive valence and high intensity, as reflected in the high ratings of for example 'power' and 'joyful activation'. Groove-based music associated with a more contemplative quality of listening and atmospheric expression, such as the triphop piece "Teardrop", also seems to elicit positive feelings, although with a low intensity, as in feelings of 'nostalgia' and 'peacefulness'. Generally, negative feelings, such as 'tension' and 'sadness', were relatively uncommon across all music conditions (although significantly more common for "Teardrop"). Furthermore, as there were no significant differences between ratings of "Sex Machine" and participant-chosen pieces, it seems that the experience of "Sex Machine" more closely resembles the experience of groove-based music with which listeners have a personal relationship. This assumption was supported in the interviews, in which participants referred to dance and movement as the most effective response when getting into the groove:

> It's got a direct line through my heart to my feet, you know. You don't need drink or drugs to get up and dance, for met it's just from your heart to your feet (P5).

These indications give reason to assume that up-beat dance-inducing music represents groove-based music to a greater extent than contemplative triphop, in terms of listeners' recognition. These findings also concur with Madison's research (2006), as the physical response seems to be particularly influential when listening to groove-based music.

F. Summary and Limitations

This experimental study reveals that groove-based music can elicit physiological responses, and that listeners experience arousal particularly when they, in addition to being highly familiar with the music and liking it, have a personal connection with it. Furthermore, 'peak responses' in HR, SC and RESP were elicited by 'peak events'. These were large-scale variations, such as temporary removal of textural layers, instrumental breaks and gradual introduction of new textural layers. The peaks seemed to be accompanied by feelings of anticipation, which therefore seem plausible as cognitive processes eliciting physiological responses to groove-based music. Indications of heightened and sustained arousal were not consistent enough to be confidently interpreted as characteristic for the experience. The experience of specific emotions, feelings and affective states seems to depend on the expression and genre of the music. Up-beat funk elicits positive responses with high intensity, while feelings experienced through contemplative listening to down-beat triphop are positively valenced while low in intensity. It appears that up-beat groove-based music more closely represents listeners conceptions of groove, due to its physical effect of making listeners want to move and dance.

This finding elucidates an important limitation of the present study. As the desire to move and dance seems particularly prominent, it can be questioned whether measurements of physiological arousal are suitable for investigating affective responses to groove-based music. As participants were required not to move, to prevent measurement noise, it is possible that the inhibition of movement affected the physiological responses. However, until equipment that is not sensitive to movement is available, this problem cannot be avoided by researchers interested in physiological responses to music.

Several other limitations must be noted. Firstly, the challenges encountered with measurements of baseline in physiological measurements required some alterations to the experimental design. Having to redefine the length of baseline-periods for SC, but not for HR and RESP might have affected the results of these parameters. Future researchers are advised to avoid these methodological problems by monitoring levels of arousal until stabilized before recording baseline-periods. Secondly, the present study is limited in number of participants. Only 10 individuals participated in the study, which hindered any statistical investigation of gender- and age-effects. Nonetheless, it is believed that the current results and implications are an important contribution to the largely ignored study of affective experience of groove-based music and that the complexities encountered have highlighted important aspects to be considered when investigating the experience of groove-based music in the future.

IV. GENERAL DISCUSSION

Theoretically, large-scale variations, such as temporary removal of textural layers, gradual introduction of textural layers and instrumental breaks, can be interpreted as structural deviations inhibiting structural tendencies. However, although these structures function as 'peak events' eliciting 'peak responses', as revealed in the second study, it does not necessarily imply that these moments dominate the listening experience of groove. According to Danielsen (2006) and the participants in the first study, listeners "move with the music" or "get into the groove", a way of listening that is not peak-based but steady and forward-moving in synchrony with the music. However, the physiological arousal recorded in the second study chiefly exhibited 'peak responses' similar to those recorded in studies investigating classical music (Sloboda 1990; Guhn et al. 2007). It might seem like these results are contradictory and reflect a paradox: The groove mode of listening is stable and sustained, but physiological responses are peak-based. However the reflections made by A in the first study pose an interesting answer to this paradox: He described the feelings of anticipation of the large-scale changes as more important than the experience of the actual changes themselves. In this sense, the anticipation of large-scale variations is an indirect facilitator of the groove mode of listening. It thus seems Meyer's theory can be used to identify 'peak events' in groove-based music, but the affective meaning of groove cannot be fully accredited to 'peak responses'. In fact, Danilesen (2006) makes an interesting philosophical interpretation of the function of large-scale variations in groove. She claims that the groove mode of listening requires a certain level of non-reflective absorption in order to be fully immersed in the experience. Furthermore, she argues that "when the musical movement is interrupted, ones attention transfers to what is actually going on, and when the groove continues with more of the same, it is nevertheless different" (p. 199). At the instance of 'peak events', then, the listener momentarily reflects over the experience that he or she has been taken out of. But rather than attending to the 'peak event' itself, the listener attends to and anticipates the return of the groove. And when the groove returns, it is intensified. In this sense, the relationship between the groove mode of listening and 'peak responses' in groove-based music is not paradoxical but dialectical: 'Peak responses' require that the musical context is groove-based, and the groove mode of listening is amplified by 'peak events'. Therefore, although physiological responses to groove-based music seem similar to those elicited by teleologically composed music, their function is different. Future researchers might consider empirically investigating the extent to which listeners' attentional focus changes while listening to groove-based music and to what extent this affects physiological responses and the groove mode of listening.

The results from the two studies provide some indications of the emotional quality of the experience of groove. In the first study, getting into the groove was associated with feelings of anticipation and pleasantness elicited by both structural deviations and predictions within and across the basic unit of the groove, supporting the theories of Meyer (1956), Danielsen (2006) and Huron (2006). Although less consistently, the interviewees also indicated that groove elicited feelings of pleasantness from physical movement and

physiological chills. These indications were more forcefully supported in the second study. Physiological arousal was identified in qualitative reports of feelings of anticipation, complementing Pressing's theory (2002) of emotional arousal from prediction and structural tension in groove with empirical support. Emotions, feelings and affective states experienced while listening to groove were found to be chiefly positive, while the level of emotional intensity depended on the musical expression. Positive feelings with high levels of intensity, as reflected in the music's ability to elicit physical movement and dance seem particularly characteristic of the experience of groove, indicating that the desire for bodily motion found among groove listeners in Madison's study (2006) have an emotional effect. All these responses can be understood as expressions of the multicomponential nature of emotional experience, as proposed by Scherer (2004: 2005): They are cognitive, motor-expressive, physiological and subjective affects. Furthermore, they seem to be described by participants in both studies in terms of how these affects are felt, supporting Scherer's proposal that experiences of music should be understood as feelings rather than specific emotions. In this sense, emotionality in groove becomes an expression of the positive affective changes felt as a result of groove and the impact of these feelings. This seems likely to be the way the word 'emotional' was used in both of the studies:

> Sometimes I'm in the mood to listen to something just really rhythmical (…). Just a drum machine and someone rapping over it, sometimes that would give me tingles, just hard, hard drums and rapping over it! And it's just rhythms against rhythms really. And that would give me an emotional experience out of it (L).

The reference to emotionality might reflect a meaning less psychologically defined and more generally accentuating as often encountered in popular discourse, as when referring to a person's susceptibility to being psychologically affected by something (an 'emotional' person) or the property of something with the ability to psychologically affect someone (an 'emotional' film). Referring to the experience as 'affective' might in fact be more suitable, if one understands it as less emotionally specific and more generally psychologically influential: When we get into the groove, we can experience a number of changes in our physical and mental senses, and these changes *feel* good.

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